Technology-scanning Capability - A Scale to Measure Firms' Ability to Sense or Respond to Changing Technology Landscape

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Abstract

A construct called technology-scanning capability has been conceptualized that measures firm's ability to sense or respond to the changing technology landscape. The second-order reflective construct was found to have four first-order constructs named as TechInfo (i.e., information gathering about ongoing technological development), TechAlign (i.e., aligning future technology development with technology trend in the market and compatible with internal technology assets), TechRespond (i.e., responsiveness to collected technology-related information) and TechExploit (i.e., exploitation of existing technology portfolio). The components provide a theoretical understanding useful to the practitioners who want to design the business processes and encourage cultures that facilitate development of stronger technology-scanning capability in their organizations.

Keywords

Environmental Scanning; Technology Scanning; Capability; Scale Development

Introduction

This study defines an important capability of firm- 'technology-scanning capability' or TechScan. TechScan capability makes firms aware of technological opportunities so firms can license, acquire, develop or re-use the relevant technologies, which facilitates the finding of technological solution to an identified or anticipated customer problem. Following literature on 'high-velocity' environments, as information and prior knowledge quickly become obsolete in such environments (Barney 2001; Levitas and Chi 2002; Bourgeois and Eisenhardt 1988), a combination of literature search and opinion survey both on experts and practitioners was used to develop a scale to measure firm-level technology-scanning capability. This capability enables firms to detect 'weak signals' (Ansoff 1975) that are early indications of future changes in technology domain. Based on these early indications, firms can respond in a timely manner as prescribed by the sense-and-respond framework (Haeckel 1999; Haeckel 2000). This capability of firms is demonstrated in the richness of sources of information and their ability to process the collected information and orchestrate a response based on the insight gained through processing of the information.

Traditionally, firms have engaged in the practice of environmental scanning (Jain 1984; Smeltzer et al. 1988; Ahituv et al. 1998; Beal 2000; Choo 2001) to inform their decision-making. Over time, the traditional way has changed and firms are increasingly engaging in targeted information seeking (Daft et al. 1988; Dedijer 1999; Raymond et al. 2001; Raymond 2003). Haeckel (1999) proposed that enterprises operating in dynamic environments have to be adaptive and suggested that the success of these firms can be explained by a sense-and-respond framework. In a paper on the design and nature of organizations in the Information Age, Huber (1984, p. 928) explained that in order to avoid failure, firms need to emphasize decision making, innovation, and information acquisition and distribution. Taking a holistic view, he identified that firms need to focus on 'post-industrial technologies, structures and processes that would enable them to successfully engage in the post-industrial environment and to become viable post-industrial organizations'. The sense-and-respond framework emphasizes firms' need to understand the changes in its business environment and the framework provides a specific guideline regarding how to remain viable within the evolving environment. Firms using this framework invest in early detection of 'weak signals' (Ansoff 1975) to broaden their 'peripheral vision' (Day and Shoemaker 2006, Haeckel

2004). A sense-and-respond mindset helps firms to identify weak signals what may first appear to be random noises and be imagined into a sense-making pattern in order to make decisions that enable firms to respond to these changes happening in their business environment.

Potential Scale Items for Technology-Scanning Capability (TechScan)

Raymond et al. (2001, p. 136) suggested that technology-scanning is a multi-dimensional activity that not only spans the technology domain but also includes other functional areas such as marketing and production. They stated, "scanning activities should be managed by someone who is accepted by the other members of the organization and who has decision-making authority," implying that technology-scanning activities are of great importance, which require access to the top management of the firm. Julien et al. (1999) used a four-dimensional model to measure technology-scanning: strategic orientation, types of information, sources of information, and scanning practices. They also included four other contingency factors in the measurement matrix: entrepreneur's profile, information network, firm's characteristics, and environmental uncertainty. Raymond et al. (2001) used an adapted model by means of the replacement of the 'strategic orientation' dimension in the Julien et al. (1999) model by 'scanning objective', and by adding a fifth contingency factor named 'technological attributes'. Van Wyk (1997) took a process view to define technology scanning, and offered the following four-step process:

1. Preparation: defining the landscape to be scanned, and setting up an agenda.
2. Observation: exploring the technological frontier.
3. Interpretation: identifying landmark technologies that serve as indicators of the main thrust of technological advance.
4. Evaluation: using the list of landmark technologies to identify technological potential and re-examine the company's own technological base.

The literature failed to make consensus in terms of what should be the objectives of a technology-scanning process and about the specific steps that firms should follow in order to achieve the stated objectives. There is also another distinctive aspect of technology-scanning literature: some are more focused on strategic and long-term perspectives (e.g.Van Wyk 1997), while others are narrow in their focuses (e.g. Julien et al. 1999). A grounded theory approach (Martin and Turner 1986) was taken to develop the scale to measure the level of technology-scanning capability (TechScan) of a firm; and the TechScan construct in this paper focuses on both strategic and operational components. Another important distinction of the TechScan construct is that it considers not only which options are available from a technological viewpoint, but also which of the possible options are more aligned with the market trend. In other words, a strong technology-scanning capability within the firm should enable it to assess the alternative technological options - that is, it should enable the firm to find out which options are preferred compared to others, so that managers can make an informed decision.

Empirical studies from extant literature were used to identify potential items for the technology-scanning capability scale. Specific studies on the success and failure factors of new product development were identified from the literature primarily on new product development, technology management and other related disciplines. National innovation surveys conducted by Statistics Canada were included for their comprehensiveness. Different theoretical aspects of technology-scanning capability were also examined from literature. The theoretical and empirical findings reported in extant literature were used to analyze and prepare a list of potential items as mentioned below.

Management Support for Technology Scanning

Management support has been identified by many authors as an important factor in the development of technology related information gathering (e.g. Peters 1991; Cooper and Kleinschmidt 1995; Mishra et al. 1996). When a firm's top management recognizes the importance of technology-scanning, it is likely to better facilitate the processes to develop this capability. How the resources of a firm are engaged at a specific time is usually decided within an overall strategy framework. Most of the firms in a given industry are faced with similar factors in the business environment; who compete for the same super-set of customers and even in some cases, in which these firms hold similar types of tangible resources. However, not all the firms perform at the same level in response to the changes in customer choices or changes in environmental stimuli. This becomes the outcome because different firms approach the issue of value creation for their customers in different ways based on their strategic orientations. A firm with a mature approach to technology scanning is expected to view competition in the market as an ongoing process of identification of methods, techniques and processes that enable itself to address customers' needs and problems effectively in a cost-competitive way. In addition, these firms would constantly be on the lookout to define new markets and re-define existing markets based on their insight of future technological developments. The firms would also make policies and organize activities in a way that emphasize an institutional climate of creativity, innovation, and voluntary participation of all employees. Four potential items were included, one item to capture each of the following four aspects of management support, in the technology-scanning capability scale.

Technology-scanning May Start Where Market Orientation Ends

One of the major aspects of market orientation is the firm's response to the market information that it collects through market orientation practices. Jaworski and Kohli (1996, p. 122) emphasized this component in separating market orientation from another parallel concept of market information processing by saying: "They are distinct in that market orientation also includes responsiveness - the use of market information for making decisions and taking actions." Technology scanning may be triggered by this need to respond to market information. Once a problem or a need of the customer is identified, technology-scanning capability allows the firm to find a suitable way to address the problem and fulfill the need of the customer. Extant empirical research (Gerstenfeld 1976; Cooper 1979; Cooper 1980; Maidique and Zirger 1984; Cooper and Kleinschmidt 1987; Cooper and Kleinschmidt 1995; Mishra et al. 1996; Di Benedetto 1999; StatCan 2003) pointed to evidence that factors responsible for a higher level of market orientation are often a precondition for a successful new product development program. Di Benedetto (1999) examined whether firms had adequate marketing skills and resources; while Cooper and Kleinschmidt (1987) asked whether a firm's new products solved a problem for a customer.

Focus on Technology

When facing with a new challenge – such as new customer needs, changing pattern in customer preference, regulatory change, or environmental concerns – some firms emphasize exploring the technological options that might be used as opposed to resorting to other tools of competition, such as price manipulation and advertisement. This is not to say that those other tools are not considered, but an emphasis on technology may be predominant in the culture of certain firms compared with others in a similar situation. Other than this inherent nature of a firm's management choices and practices, internal factors might, due to inertia, also lead to dependence on a certain technology. However, when the firm has a culture of technological alertness shown by many firms, then unsatisfactory operations, inefficient production processes, or obsolete technologies being used may lead to a search for new technological solutions to mitigate the problems. Mishra et al. (1996) examined whether firms considered the newness of a certain technology when making decisions. A survey conducted by Statistics Canada (1996) also supported this item to be included in the technology-scanning capability scale.

Facilitation of Voluntary Participation of Employees

Managers of a firm may have some reasonable expectations on the outcome of an innovation effort, but the process has its inherent uncertainty. It would not be an overstatement to say that the outcome of innovation process is more uncertain than any other business processes that may exist within a firm. Once the goal of an innovation effort is defined by identifying the problems and needs of the customers through market orientation processes, individual members identify or locate the potential techniques and technologies that can be used to satisfy those identified customer problems and needs. Peters (1991, p. 14-15) characterized these processes within a modern firm as follows: "By definition, you can never force anyone to be innovative, to engage in continuous improvement, to use their heads to make things better every day. Thus …we have no option but to treat everyone as volunteers".

Leavitt (1996), in the description of organizational conditions for productive and innovative behavior, asserted that these four characteristics are important: a democratic approach, a competitive atmosphere, leadership, and task orientation. Technology scanning emphasizes task orientation when triggered by some market information. Leavitt's other three criteria result in a voluntary nature of the organization as these conditions improve motivation of employees. In essence, for the individual members of the organization to engage in effective technology scanning, firms encourage their employees to contribute voluntarily. Empirical survey designed by Cooper and Kleinschmidt (1995), Statistics Canada (1996) and Statistics Canada (2003) provided evidence that this item was often measured; for example, Cooper and Kleinschmidt (1995) who examined whether firms gave their employees time-off for 'creative things'.

Organizational Readiness through HR Policy, Culture, Processes and Tools

Part of management's job is to facilitate such a climate within the firm, both in terms of policy and infrastructure, which helps employees to contribute to an effective manner. Moreover, employees may be recruited in a way to make the experience portfolio of the workforce of the firm as diverse as possible. This strategy allows the firm to benefit from the technology brokering effect (Hargadon 2005) that evolves naturally when the personnel has a knowledge-base that pertains to many industries. Moreover, firms create multi-disciplinary teams for new product development in order to take advantage of different viewpoints of the employees from different functional areas (Cooper and Kleinschmidt 1995). Once suitable personnel is hired, firms support them with: proper tools, such as access to data mining software; processes, such as formal technology assessment protocol; and policies, such as providing support for employees to attend conferences, seminars and tradeshows - thus ensuring effective information gathering and processing. Empirical researches designed by Cooper and Kleinschmidt (1995), Cooper and Kleinschmidt (1987), Maidique and Zirger (1984), Gerstenfeld (1976), Statistics Canada (2003), Statistics Canada (1999), Statistics Canada (1996) supported this item. For example, Statistics Canada (2003) queried whether firms offered off-site training to workers in order to keep skills current, or whether firms maintained databases on good work practices, lessons learned from different projects, or product development efforts.

Use of Numerous and Diverse Sources of Information

As products are becoming more dependent on advanced technology and as product life cycles are being shortened (Clark et al. 1984; Cravens 1986; Achrol 1991; Sood and Tellis 2005), R&D departments of producers and manufacturers have less time to spend on any specific product. This time constraint and other competitive forces encourage firms to seek external information to discover technological development elsewhere which might be useful to them. Among the researchers who investigated other sources of innovation differing from conventional line of thought that says 'only manufacturers innovate', von Hippel (1988) argued that there are various constituents in any product innovation; for example: users, manufacturers, suppliers and distributors. All these constituents have differing levels of incentives and profiting mechanisms when an innovation is evaluated in question. von Hippel also argued that these constituents have access to varying degrees of resources and expertise available to themselves for improvement on an existing product or for innovation of a new product that fills a market need for an existing or yet-to-be-articulated demand. By the identification of more sources to look for information and ideas for innovation, these findings help those firms searching for new ways to satisfy their customers. The sources for ideas are: employees, users, customers, manufacturers, suppliers, distributors, research community, competitors, professional associations, business and regular press, government regulators and other stakeholders. Strong support exists for this characteristic of the firm's behavior according to many empirical research publications (Maidique and Zirger 1984; Cooper and Kleinschmidt 1987; Cooper and Kleinschmidt 1995; StatCan 1996; StatCan 1999; StatCan 2003). Cooper and Kleinschmidt (1995) examined whether customers were involved in an innovation effort. Maidique and Zirger (1984) asked if their participants had more interaction with users in the development stage; they also examined whether project teams interfaced more with external resources and whether innovations depended more heavily on technologies that were developed externally. A source of information can reside at many places. Information may be found within immediate organization, or outside it but within organizational network.

Information may also be sourced externally – either from within national boundary or sourced internationally. Four potential items were included in the scale to include all the possible choices for a source of information.

Responsiveness to Technology Scanning

A firm may use the result of technology-scanning activities in different situations – to aid day-to-day operational decision-making and long-term strategic decision-making. In all the stages of business execution, managers are faced with making decisions, selection among alternatives. The maturity of the technology-scanning activities becomes clear if the outcome of the process is used as an input at various decision points. An optimum level of technology-scanning activities can serve as an effective decision support system for management. Among the empirical studies reviewed, Statistics Canada (2003) asked participants if they purchased rights to use patents and non-patented inventions, licenses, know-how, trademarks, software and other types of knowledge from others for the development of new or significantly improved products and processes. Such purchasing would be a response to information that the firm might have gathered, a characteristic for which Statistics Canada (1999) also lent support. Potential items capturing this issue asked if firms respond to the finding of technology scanning activities either at the operational level or at the strategic level. Items also examined the issue based on individual perception and anecdotal evidence for such responsiveness. In total, this topic accounted for four potential items.

Extent to Which a Shared Sense of Future is Developed

Senge (1990) identified 'building a shared vision' as one of the five component technologies that enabled organizational learning. Firm's technology-scanning activities facilitate the building of a shared vision about the future of the firm and the firm's role within the industry or market. This shared sense of outcome would enable the firm to engage its resources towards a focused direction in a coordinated way. Some of the measurement of these processes would be quantitative (e.g., whether the firm processes and activities connect different functional areas) while some others would be qualitative (e.g., whether the individuals often disagree with colleagues from other functional areas and teams). Among the works that performed empirical reviews, Di Benedetto (1999), Cooper and Kleinschmidt (1995), Maidique and Zirger (1984), Statistics Canada (2003), Statistics Canada (1999) and Statistics Canada (1996) broadly supported this concept to be inclusive in the measurement of technology scanning. Di Benedetto (1999) examined whether interdepartmental committees were set up to allow departments to engage in joint decision making. Statistics Canada (1996) asked participants how well on the consensus on decision making was done. Maidique and Zirger (1984) examined whether innovation teams had more project reviews during development and commercialization than that at other times. This component of technology-scanning construct measured how strongly different functional areas of a firm were integrated with a single vision. The potential items examined whether the perception of shared sense of future existed either within the organization or among all the stakeholders of the firm. If there were anecdotal evidences of such shared sense existed either within the organization or among all the stakeholders which were also noted. This concept accounted for four potential items in total.

Achieving Tangible Goals Through Technology-Scanning Activities

Apart from the general focus on the technological aspect of problem solving and of finding answers in the technological field, firms try to achieve certain goals during their innovation efforts. The literature from technology diffusion, innovation and marketing lent support in identifying the specific goals to which firms pay specific attention. These specific goals are: a) to notice a technology trend, b) to be compatible with current competences, c) to exploit the current technology portfolio of the firm, d) to distinguish between incremental and radical innovation, and e) to pay special attention to the cost reduction implications of technological development. Following is a detailed discussion on these five goals that firms often try to achieve and one potential item has been included to represent each of these goals.

Synergy with Technological Trend in the Marketplace is Emphasized

Firms use technological innovation, among other organizational factors, to solve an identified customer-related problem or to design a new product. To perform effective innovation, firms need to stress that all possible sources of information are used to gather the innovation ideas. Firms might not find a readily available technological solution to an identified problem; instead, there might be several potential candidates for future investigation. Given these scenarios, firms decide to choose one or more of the competing alternatives to implement or to investigate further. A strong technology-scanning capability may enable the firm to identify the complementarities of technologies so that the right decision can be made, thereby taking advantage of existing trends in the market and increasing the likelihood of improved adoption rate of their offerings and eventual market success of innovation.

Success of a particular new product or an innovation that is introduced to the market depends highly on its level of adoption among the prospective customer base, an adoption that in turn depends on many other factors. Some of these factors can be endogenous to the innovation itself, or they can be exogenous to the specific innovation in question. It is difficult to measure the impact of exogenous factors on the success of an innovation, which are generally recognized as responsible for widespread, across-the-board adoption of an innovation. Adoption of a product in a certain industry often depends on the adoption of some other related product within the same industry. Similarly, developments in other industrial sectors might also influence innovation in a given industry. This inter-dependence among different innovations in a single industry or multiple industries makes the study of technology-change and its role on the success of a certain innovation more challenging and interesting.

As described by Rosenberg (1982, p. 60), the complementarities of different innovations can be better understood by taking a systems perspective. Within any socio-technical system, the combined effect of stand-alone separate improvements has a much greater effect than the cumulative individual effects when considered separately, as supported by Rosenberg: "It is the characteristic of a system that improvements in performance in one part are of limited significance without simultaneous improvements in other parts, just as the auditory benefits of a high-quality amplifier are lost when it is connected to a hi-fi set with a low-quality loud-speaker." This is likely the reason why even apparently spectacular breakthroughs do not always bring exciting changes instantaneously – only a gradually rising productivity and adoption curve is observed in many cases. So, it is not enough to contemplate the usefulness of a stand-alone product; rather manufacturers have to think about the synergistic dynamics of the product in question when integrated with other existing and anticipated future products in the market. Since the widespread adoption eventually defines the success of the innovation, the synergies are sometimes more important than the stand-alone features.

When an innovation by a firm is in line with the trend in the market place, it is more effective in that it needs much less promotion, marketing, and sales efforts than when it is not. Also, the literature on increasing return economics (Arthur 1989) and technology diffusion (Geroski 2000) suggest that the development effort which fits with technology trends are more likely to become successful in the market. Empirical research designs reported by Cooper (1980), Maidique and Zirger (1984), Statistics Canada (2003) and Statistics Canada (1999) lent support for this item. Maidique and Zirger (1984) examined whether the chosen technological options of firms are closer to the state-of-the-art technologies. Statistics Canada (1999) asked whether firms emphasized active involvement in developing new industry-wide standards to bring their internal technological knowledge and development efforts in-line with the existing trends in the market place.

Compatibility with Firm's Existing Technologies and Resources

When a broad-level decision regarding future technological path is made, firms are also concerned with the compatibility of new technology with their existing competencies. Issues of compatibility of the chosen technology with the existing resources of the firm, such as marketing, sales and distribution, management and market research skills, and production facilities (Maidique and Zirger 1984; Stuart and Abetti 1987) have to be investigated. Firms consider the existing technological resources – know-how, investment and ownership (if any) – while deciding on new innovation pathways in relevant cases. Other issues regarding both complementarities with existing technology competences and complementarities of R&D with other functional areas are also considered.

Song et al. (2005) examined marketing capabilities, technological capabilities and their complementarities (interaction); they found that the role of the complementarities was more important in the high-turbulence environment than in the low. Compatibility with firm's existing resources has strong support in the empirical research reported by Di Benedetto (1999), Cooper and Kleinschmidt (1995), Cooper and Kleinschmidt (1987), Cooper (1979), Maidique and Zirger (1984) and Statistics Canada (2003, 1996). Cooper (1980) found that firms with successful product development efforts had compatible engineering skills. Cooper and Kleinschmidt (1980) examined whether firms had a good fit between the needs of the project and R&D, or product development skills and resources. Maidique and Zirger (1984) reported compatible sales force and distribution resources and skills in firms that have successful product development effort.

Exploitation of Technology Portfolio in New International Market

Erickson et al. (1990) described a product-market matrix for presenting the four strategies that a firm can pursue when exploiting full potential in market and product domains, as shown in Figure 1. Using geographical areas as the boundary of market, these four strategies can be used to discuss how the firm approaches the issue of engaging in new markets in international locations. From strategic point of view, all four cells shown in the figure offer different opportunities and risks in terms of the investment requirement and potential return of investment. Cell A indicates an opportunity for ongoing cash flow from the current products being sold in existing markets. Strategies related to Cell B and Cell C offer new possibilities with reasonable risks as firms enter into new endeavors either with known products or in a known market – so the firm can depend on its existing competences to a certain extent. Among the four strategies, Cell D offers more risks, as the firm needs to acquire new market competences and new technological competences in this case. While exploring the options for internationalization of products and services, firms have traditionally considered the 'psychic' closeness of the target market as a major decision factor. A slightly overlapping yet distinct criterion that distinguishes different international markets is the issue of susceptibility to new and technologically advanced products. Markets in Japan, Western Europe, and South Korea are characterized by such susceptibility. Thus, when a more advanced product is developed using current competences, the firm may consider certain international markets for initial kick-off, sometimes, even before introducing the product in domestic market.

FIG. 1: PRODUCT-MARKET MATRIX: FOUR STRATEGIES

	Existing Markets	New Markets
Existing Products	A	C
	Improve value and cost	Adapt know-how to new markets
New Products	B	D
	Leap forward in value and cost	Radical product and market diversification

Source: Erickson et al. (1990)

'Born-global' and 'knowledge-intensive' firms (Bell et al. 2001) often target international markets when they introduce breakthrough products and technologies, thus defying the assumption that Cell D offers more risk. Alternately, a domestically established firm may seek to acquire new technologies by collaborating with or acquiring an international firm. The pervasive spread of ICT technologies – such as www, email, fax, RSS, blog, twitter, social networking tools – has enabled firms to gain access to the information about new international markets, allowing identification of new market segments that might be ripe for exploitation using the existing technology portfolio of the firm. Technology-scanning capability enables firms to make these links with existing products and services to possible new international markets. Three consecutive surveys on innovation by Statistics Canada (2003, 1999, 1996) examined this specific item. For example, Statistics Canada (1996) asked whether innovation opens up new international markets, and Statistics Canada (1999) examined if innovations helped increase firm's domestic market share.

Distinguish Between Ways to Make Incremental vs. Radical Innovation

Among the categories of innovation found in literature, the dichotomization as incremental and radical types is prominent. There are many aspects of this classification of innovation – it could be based on the technologies that firms use, or it could be based on the type of customer choices and needs being addressed. When a radically new innovation is introduced by a firm, it needs to employ relatively abundant resources to make the radical innovation known to the potential customers – making the marketing and sales effort more expensive. Once the innovation is introduced, competitors start crowding the same market segment with other similar and 'me too' products and services. Due to both competitor pressure and high initial cost for invention and marketing, the profit from initial radical innovation may not be as high as expected for the firm who introduced it first. In contrast to radical innovation, incremental innovations face fewer difficulties and lower cost in terms of both development cost and market creation and penetration. Hence, incremental innovation could yield a higher rate of return and profitability. Harrington (1995) provides empirical evidence showing that continual (incremental) process improvements provide higher gain than achieved with breakthrough (radical) process improvements.

Based on the discussion presented above, it is evident that while a firm would want to continue innovating through radical products and processes to gain access to new uncharted markets and production environment, it also needs to focus on finding techniques and technologies to introduce incremental innovations to the existing products and services. Both of these types of innovations would benefit a firm in two distinct ways, and which one becomes the more important would depend on the strategy it pursues. In general, it can be said that the technology-scanning capability enables a firm to discriminate between the two types of innovation. Cooper and Kleinschmidt (1987), Cooper (1980, 1979), Maidique and Zirger (1984), and Statistics Canada (2003, 1999, 1996) reported that empirical research supported this technology-scanning item. Among these studies, Maidique and Zirger (1984) found that many product developments had become radical with respect to world technology.

Specific Attention is Given to Achieve Cost Reduction in Existing Products

Adoption of new technologies enables a firm to reduce costs in different stages of the product life cycle. The incremental cost-reductions are important factors determining the price that customers pay for a product, especially when competition is high. Therefore, firms give special attention to different ways to reduce direct and indirect costs during development stages so that they have the needed flexibility in pricing products and services. Empirical research designs by Cooper (1980, 1979) and Statistics Canada (2003, 1999, 1996) supported this technology-scanning item to be included in the scale. Cooper (1980) queried whether new products enable customers to reduce costs. Statistics Canada (1996) examined whether innovations enable firms to reduce their production cost by reducing unit labor cost and production time, and by cutting consumption of materials and energy.

Refining TechScan Items through Opinion Survey of Experts and Practitioners

Once the findings from both the theoretical and the empirical literature were combined, a tentative scale with twenty-one potential items was created. The next step was to validate these items through in-person opinion survey of experts and practitioners. A convenience sample of ten researchers and practitioners were interviewed to get their view on the individual scale items. This step of the exploratory stage helped refine the vocabulary and actual questions to be asked in the final confirmatory stage questionnaire (Aaker et al. 2001). The list of experts represented a total of 26 industries through their past experiences. Appendix shows the demographics of those interviewed. It is evident from the list that the interviewees represented a wide variety of industries and sectors; their input was used to generalize the questions as much as possible. A structured survey was conducted using a set of questions in which participants were asked to rate different items of technology-scanning construct. The findings from this stage of opinion survey supported the initial items proposed after reviewing the relevant theoretical and empirical literature. It is worthwhile to note that the variety in the affiliations and experiences of the interviewees did not translate into much variance in their opinions. One explanation of this could be based on the solid theoretical foundation of these items and their appropriateness for the topic in question. The average score for each of the items was supportive, and these results were retained at the conceptual level. However after further consideration and review, a few of the items were merged together for greater clarity and to avoid redundancy. Finally, sixteen items for TechScan scale were adopted to be included in the survey. The detailed descriptions of these refined items are included in Table 1.

Data Collection

A survey instrument was developed after refining the items for the technology-scanning capability (TechScan) scale and improving the wording for the actual questionnaire. The resulting survey was delivered through the web to a national sample of managers of different manufacturing firms. A web-based survey was selected as a methodological option because of the benefits of speed, reasonable cost, and easy accessibility, and because of the geographic dispersion of the target participants (Ilieva et al. 2002; Deutskens et al. 2004; Cole 2005; Evans and Mathur 2005; Deutskens et al. 2006; Deutskens et al. 2006). The Industry Canada database of Canadian Company Capabilities (CCC 2008) was used to find contact information of Canadian companies who are engaged primarily in manufacturing. When the contact email information of C-level officers (e.g., CEO, CTO) was not available, preference was given to recruit someone from General Management, R&D or Marketing. A total of 17,272 usable contacts (i.e., email addresses) of firms who listed their primary business activity as ‘Manufacturer / Processor / Producer’ were available at the time in the database. These firms were invited through email to participate in a web-based survey. Effort was made to increase the response rate by development of a user-friendly interface, by careful design of the questionnaire so that the questions were unambiguous, by use of reminders, and by timing of the survey. Also, the service of Survey Research Centre at University of Waterloo was used to conduct the survey with the expectation that the reputation of the university would help increase the response rate. There were 467 participants who provided useful information for further analysis. The contact rate for the survey was 77.3%, while the cooperation rate was 3.1% with effective response rate of 2.7%.

Finalizing the Scale to Measure Technology-Scanning Capability (TechScan)

The items of the TechScan scale were finalized including its underlying factors following guidelines from Churchill (1979), Gerbing and Anderson (1988), DeVellis (2003), Marsh and Hocevar (1985), Spector (1992), and Worthington and Whittaker (2006). The scale to measure technology-scanning capability was modeled as a reflective construct. Reflective constructs can be independently modeled without interaction with other constructs (Rossiter 2002). Hence, the results are more generalizable and can be compared across studies. Indicators of a reflective construct are interchangeable to some extent and dropping a single indicator does not alter the conceptual domain of the construct.

Following the guidelines of Churchill (1979, p. 68), the 16-item pool of indicators were first examined for the existence of a common core. In other words, the individual items were examined to see if they belong to the ‘domain of the concept’. All but one item had a value more than 0.30 for item-to-total correlation value. The other item (TechScan16) had an item-to-total correlation of 0.293. Moreover, the Cronbach’s Alpha reaches its second highest value when this same item is deleted from the indicator list compared with other Cronbach’s Alphas when other items are deleted sequentially. The Cronbach’s Alpha reaches its maximum value when another item (TechScan14), which has an item-to-total correlation of 0.329, is deleted. Because of these reasons, items TechScan16 and TechScan14 were possible candidates for being dropped from the final list of items for the scale. However, at this point, all the items were retained for further examination. Next, Bartlett’s (1950) Test of Sphericity was performed; the corresponding findings (Chi-Square=2692.39, df=120, $p < 0.00$) indicated statistically significant values. However, this test is not sufficient by itself when the sample size is relatively large (Tabachnick and Fidell 2001). Worthington and Whittaker (2006) also suggested that researchers should provide additional evidence of factorability when cases-per-item ratio is higher than 5:1, which was true for the current study. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (MSA) was used as one such additional evidence of factorability. Tabachnick and Fidell (2001) note that a KMO-MSA value of 0.60 or higher was required for factorability. A test for this criterion resulted in a value of 0.887 for the TechScan scale items, which was satisfactory.

Factor Analysis (FA) of TechScan Items

A factor analysis was performed using SPSS 16.0 with principal axis factoring and promax rotation that revealed four factors. These four factors of the TechScan construct suggested by the factor analysis were also conceptually coherent. Indeed, Worthington and Whittaker (2006, p. 822) suggested: “Conceptual interpretability is the definitive factor-retention criterion. In the end, researchers should retain a factor only if they can interpret it in a meaningful way no matter how solid the evidence is for its retention based on the empirical criteria”. One of these four factors, however, did not pass the strict criteria set forth by Tabachnick and Fidel (2001), since the correlation between items of this two-item factor is less than 0.70. Three of the items were deleted as items TechScan10 and TechScan16 did not load with any of the factors with loading of 0.32 and a third item (TechScan06) loaded onto more than one factors with cross-loading less than 0.15 difference from an item's highest factor loading making it difficult to include the item in either factors (Worthington and Whittaker 2006). The corresponding Cronbach's Alpha of these four factors was at an acceptable level. The thirteen-item Cronbach's Alpha was found to be at 0.866. Table 1 shows the detailed grouping of the items, corresponding loadings of TechScan scale, Cronbach's Alpha of the factors and cross-correlations among them. Following is a discussion on the naming of the four retained factors for TechScan scale.

TechInfo (Information Gathering about Ongoing Technological Development)

Six items were included in the first factor. The items correlated strongly, and they had a Cronbach's Alpha of 0.809. These items had a common conceptual thread among them that was related to the information gathering about technological field. Some of the items were directly concerned with different types of information sources; others were more policy-level characteristics and features of the firms that enabled gathering of technological information effectively. This 6-item factor explained 35.23% of the variance, and was the strongest of the four factors in terms of contribution to the formation of the TechScan scale.

TechAlign (Alignment Future Technology Development)

Three items formed the second factor of the TechScan scale, and they together explained 4.589% of the variance. The Cronbach's Alpha of this 3-item factor is 0.708. The common conceptual theme among these items was alignment of future technology development. Firms are concerned with this issue of alignment in different contexts – alignment with technology trend in the market, compatibility with existing technological competences that existed within the firm, and keeping alignment in the technological developments that were occurring within the business network of the firm (e.g., making sure that the supply chain stakeholders were not taken by surprise). Indeed, these alignment pressures often opposed one another, yet firms needed to keep the right balance in order to achieve their business goals.

TechRespond (Responsiveness to Collected Technology-related Information)

The third factor was concerned with the responsiveness aspect of the firm's technological activity – it covered responses of the firm to both internal and external developments. Two items were included in this factor, with a Cronbach's Alpha of 0.854. Combined, these two items explained 3.963% of the variances. Technological developments had their implications for firms' strategy and operations, and firms had to respond timely to technology-related information that had either strategic or operational implications. Together, these two items captured the responsiveness aspect of technological information gathering within the firm.

TechExploit (Exploitation of Technology Portfolio)

The fourth factor was concerned with the exploitation of existing technologies for which the firm had a direct or indirect access. This two-items factor explained 3.362% of the variance in TechScan scale and the Cronbach's Alpha of this factor was 0.586. Given the increasing global nature of competitions, firms look at new international markets to access new technologies as well as to license their existing technology portfolio. Also, firms would use their existing resources for both incremental innovation projects and breakthrough innovation projects as these different types had differing implication for the firms' overall performance. Incremental innovation would increase the likelihood of maximum exploitation of the current technology portfolio and increase short-term profitability and immediate cash-flow. Breakthrough innovations, on the other hand, increased the likelihood of firms' long-term viability. Given that this factor had only two items, it was subject to correlation criteria set forth by Tabachnick and Fidel (2001) for such factors and it could be dropped if a decision was made solely on the quantitative criteria. However, the factor was retained for its conceptual importance of current day practices in firms and for its comparable share of variance with two other factors (TechAlign and TechRespond) that were also retained.

TABLE 1 FACTOR ANALYSIS OF TECHSCAN SCALE ITEMS (N=467, A=0.866)

Items	Item Loadings	Factor Names and Corresponding Cronbach's Alpha, % Variance Explained and Eigenvalues
TechScan01: The market drives our search for new technological solutions.	0.346	Factor 1: TechInfo Cronbach's Alpha = 0.809 Eigenvalue: 6.105 % Variance Explained = 35.233 Correlation with TechAlign = 0.627 Correlation with TechRespond = 0.655 Correlation with TechExploit = 0.551
TechScan02: Technology plays an important role in our approach to tackling an issue, when appropriate.	0.644	
TechScan03: Encourages employees to explore new technological ideas voluntarily.	0.903	
TechScan04: Policies, processes and tools to enable employees to explore new technologies.	0.878	
TechScan05: Uses the information available within the organization.	0.508	
TechScan07: Gathers information from global sources when searching for new technological solutions.	0.440	
TechScan11: Makes an attempt to co-develop future development plans about its technology with other players in business network.	0.406	Factor 2: TechAlign Cronbach's Alpha = 0.708 Eigenvalue = 1.212 % Variance Explained = 4.589 Correlation with TechRespond = 0.612 Correlation with TechExploit = 0.524
TechScan12: Looks for synergy of product offerings with existing technological trends in the market.	0.759	
TechScan13: Seeks to ensure compatibility with existing technologies, resources and competencies.	0.749	
TechScan08: Responds well to any technology information that has a strategic implication.	0.763	Factor 3: TechRespond Cronbach's Alpha = 0.854 Eigenvalue = 1.079 % Variance Explained = 3.963 Correlation with TechExploit = 0.518
TechScan09: Responds well to any technology information that has an operational implication.	0.982	
TechScan14: Seeks to exploit new international markets through acquisition and sale of intellectual property.	0.737	Factor 4: TechExploit Cronbach's Alpha = 0.586 Eigenvalue = 1.006 % Variance Explained = 3.362
TechScan15: Engages in both types of innovation, namely, incremental and breakthrough innovation.	0.519	
TechScan06: Uses information from organizations in external network when searching for new technological solutions	This item was dropped since the cross-loading less than .15 difference from item's highest factor loading	
TechScan10: Employees from different functional areas usually agree on technology development path.	This item was dropped due to insignificant loadings in all of the factors	
TechScan16: Gives specific attention to achieve cost reduction in existing products.	This item was dropped due to insignificant loadings in all of the factors	

Reliability and Validity of the Construct

The technology-scanning capability was modeled as a second order reflective construct with four first-order components. According to Nunnally (1978), in order for factors to be considered as having convergent validity and reliability, both of Cronbach's Alpha and Construct (Composite) Reliability scores have to be 0.7 or greater. Fornell and Larcker (1981) further provided guidelines by specifying the measure of Average Variance Extracted (AVE) value of greater than 0.5 in order for the measurement error associated with the construct to be outweighed by the variance extracted through its indicators. The corresponding factor loading, AVE, Cronbach's Alpha and Composite Reliability value are shown in Table 2.

TABLE 2 DETAILS OF THE CONSTRUCTS' INTERNAL CONSISTENCY, CONVERGENT VALIDITY

The Construct and its factors	Order of the Construct and Alpha of Components	AVE	Composite Reliability
TechScan	2nd Order (0.866)	0.597	0.855
TechInfo	1st Order (0.809)	0.516	0.861
TechAlign	1st Order (0.708)	0.642	0.842
TechRespond	1st Order (0.854)	0.865	0.928
TechExploit	1st Order (0.586)	0.688	0.813

Future Research and Implications

It would be useful to replicate the research in different settings. A specific industry could be selected to recruit survey participants to examine if results from that particular industry exhibit similar behaviour. It would also be interesting to compare outputs among a few focal industries and examine whether a certain industry makes more use of technology-scanning capability. It would also be interesting to explore the underlying causes (e.g., competitive pressure) that might be responsible for differing levels of use of technology-scanning capability in different industrial sectors. Different components of TechScan capability may also have differing level of showing based on the industry sectors being examined. Findings of these studies will be helpful to create benchmarking device that practitioners may use as a management tool. The insight from this model could be used to improve designs of business processes that do the gathering, processing, and analyzing of information from technology domain.

Conclusion

In the face of increasingly uncertain future, today's firms are increasingly engaged in information collection, information processing and dissemination of this information in order to prepare to adapt to the new realities. The model of technology-scanning capability provides useful insights into what practitioners might pay attention to while adapting. The model of the construct complies with the generic definition of capability where a capability delivers a goal. The goal is achieved through a combination of processes, tools, knowledge, skills, and organization that are all focused on meeting the desired result (Alvarez and Raghavan 2010). The findings of this study provided important insights for practitioners as well as researchers. First, an important construct called TechScan was developed and its psychometric properties were reported. This scale could be used to measure firm-level technology-scanning capability. The usefulness of this capability is even more important since firms are becoming more interested to know about ongoing changes in technology domain externally as a result of the increasing popularity of open innovation practices (Chesbrough et al. 2006). Indeed, Chesbrough (2003) stated that the job of R&D managers involved not only managing within the company but also looking beyond the firm boundary and managing the network relations to take advantage of other firms' technological efforts. Alliances, mergers, acquisitions are also frequently used as tactical tools to practice open innovation. Hence, a better understanding of how firms may develop and improve their technology-scanning capability would be helpful to execute the open innovation strategy of firms.

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Appendix

DEMOGRAPHICS OF THE EXPERTS SURVEYED TO REFINE TECHSCAN SCALE ITEMS

#	Academic & Professional Qualification	Years of Experience	Types of firms worked with	Positions Held
1	MBA, Postgraduate	20 years	Manufacturing, Telecom, Retail, Real Estate	President
2	M.Sc., MBA (P.Eng.)	25 years	High-tech, Power generation, Nuclear	Director, Consultant
3	Bachelor	7 years	Manufacturing, Grandfather Clock Company	President
4	Bachelor (Writer / Editor)	13 years (6 yrs in software, 7 in comm.)	Software, financial, medical, hardware	Partner/ Owner; Manager, Technical Publications
5	B.Sc., MMSci	9.5 years	Automotive, Logistics , Packaging	Production Control Specialist
6	M.Sc. (P.Eng.)	9 years (7 full time, 2 part time)	Medical Research Industry	Technical Manager, R&D Engineer
7	MBA	15 years in industries, 11 in consulting	Petrochemical, Base Chemicals, Natural Gas, Food, Insurance	Systems Analyst, Lecturer
8	Bachelor	2 years	Green Technologies	Entrepreneur
9	PhD	12 years	R&D, IT Development	Research Scientist, Design Engg.
10	Bachelor	30 years	Aeronautical, Amphibious Vehicle, Gear Industry	CEO, President, Design Engineer